SOLAR-POWERING WATER RESOURCE AUTOMATION PROJECTS

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Abstract

Since many monitoring and control sites on water projects are in areas remote from the electrical utility grid, it is frequently essential to find alternative sources of power. To meet this need, the U.S. Bureau of Reclamation (Reclamation) is increasingly relying on solar energy. Sandia National Laboratories has been assisting with the design and evaluation of the solar features.

Components

The revolutionary advances of computer and communication technologies in the last 10 years have made automation technologies accessible to most water resource projects, no matter what their size. Automation technologies have proven to be a cost-effective tool for improving the efficiency of water supply and delivery systems. As water becomes increasingly scarce and, therefore, a more valuable commodity, automation systems encourage better water management, water conservation, and reduced operating costs.

The basic components for a simple canal automation site include: (1) datalogger/controller; (2) water-level sensor; (3) cellular phone, telephone or radio; (4) modem; (5) solar energy system; (6) enclosures; and (7) gate actuator. The first six items cost approximately $2,800 (in U.S. dollars) (see Fig. 1) and require as little as 4 hours labor to install. A solar-powered gate actuator costs an additional $1,500 and up and usually necessitates a larger solar panel, and in some cases an additional battery[1]. As can be seen in Fig. 1, the equipment costs for the solar energy system is less than 10 percent of the total cost.

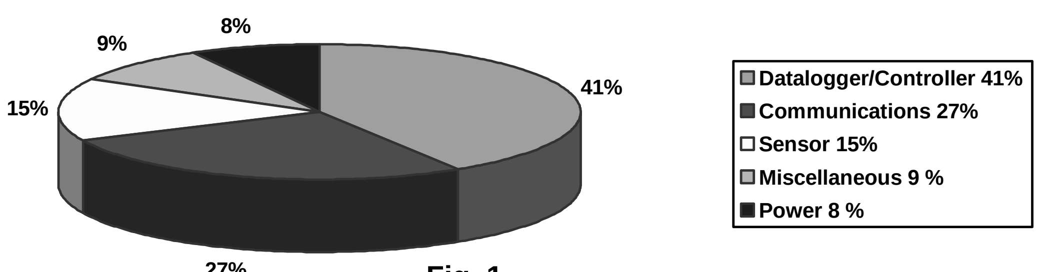

Fig. 1

The equipment cost distribution for a solar-powered monitoring system.

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A solar energy system can be as simple as a small solar panel (10 to 40 watts), a voltage regulator, and 1 or 2 deep-cycle (130 amp-hr.) lead-acid batteries. The cost for such a solar- energy system can be as little as $200 for a 10-watt system and $500 for a 40-watt system. When you compare this cost to the thousands of dollars which are frequently required to hook up to the utility grid, a solar-energy system can be a very cost-effective alternative.

Example Gate Installations

When Reclamation began designing and installing low-cost canal automation systems in 1994, there was very little enthusiasm among commercial manufacturers to make and sell 12- and/or 24-VDC (volts direct current) gate actuators. For this reason, Reclamation designers developed several prototypes that can be retrofitted onto slide gates on existing structures.

"Do-It-Yourself" Model - While developing a low-cost solar-powered gate actuator, Reclamation staff determined it that is relatively easy to attach a 12-VDC gear motor to an existing slide gate. This can be accomplished with a chain and sprocket[2]. What is more complex is measuring gate position and installing limit switches. Measuring gate position is important because it provides necessary information on the state of the automation system (and can also be used to estimate flow). The limit switches are critical because they protect the gate from being closed too tightly or opened too wide.

Frank Woodward, of Reclamation's Provo Area Office staff, has developed two prototypes which measure gate position and provide limit switches (www.uc.usbr.gov/progact). The first prototype mounts over the gate stem and is designed for a gate system where the stem moves up and down in sync with the gate (see Fig. 2). As the gate stem moves, a potentiometer tracks gate position. The limit switches are triggered as the gate moves toward its extremes.

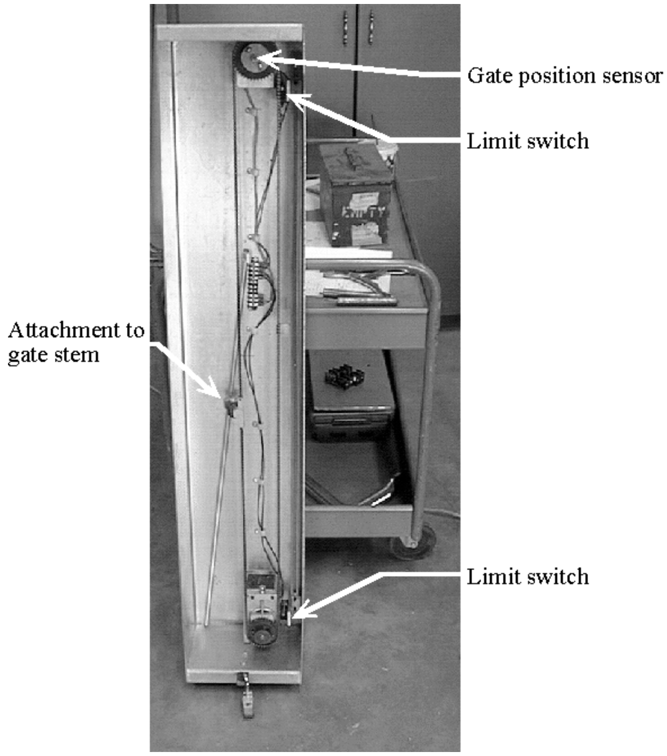

Fig. 2
The first prototype is mounted over the gate stem
and houses the gate position potentiometer and limit switches.

The second prototype (see Figs. 3 and 4) was designed for gates where the stem does not move up and down. On this unit, a gear box is attached to the gate stem lift nut with a chain and sprocket. The gear box is connected to a disk which activates the potentiometer and triggers the limit switches. Because there is increasing interest in integrating image monitoring into gate control systems, the first prototype (which covers the gate stem: a useful visual monitoring point), may not be appropriate for systems that include a camera. In addition, the first prototype is visually obvious and, for this reason, susceptible to vandalism. The second prototype overcomes these two problems.

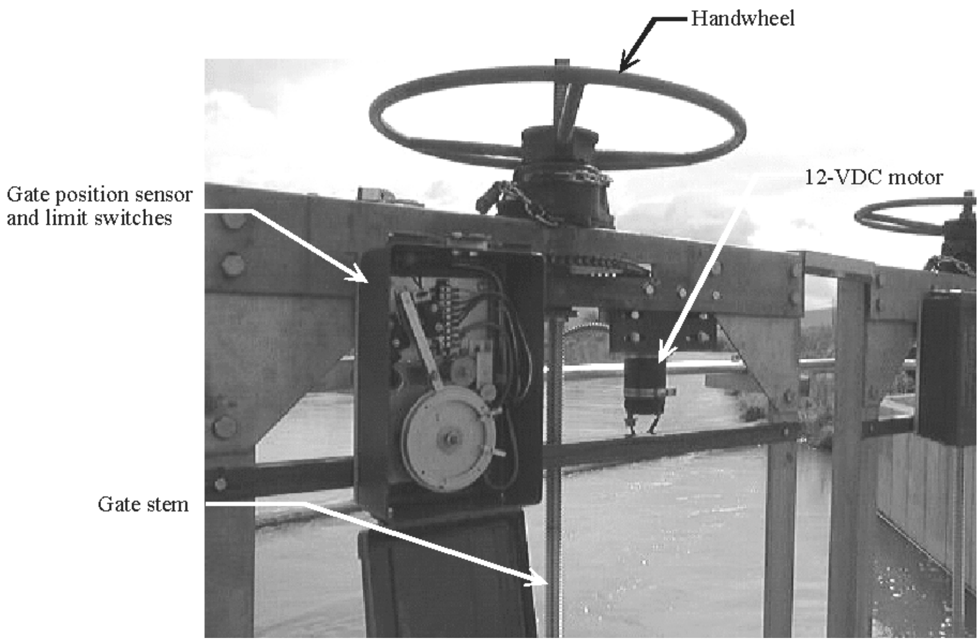

Fig. 3
The second prototype (center left) attaches to the gate stem
lift nut with a chain and sprocket and also includes
a gate position sensor and switches.

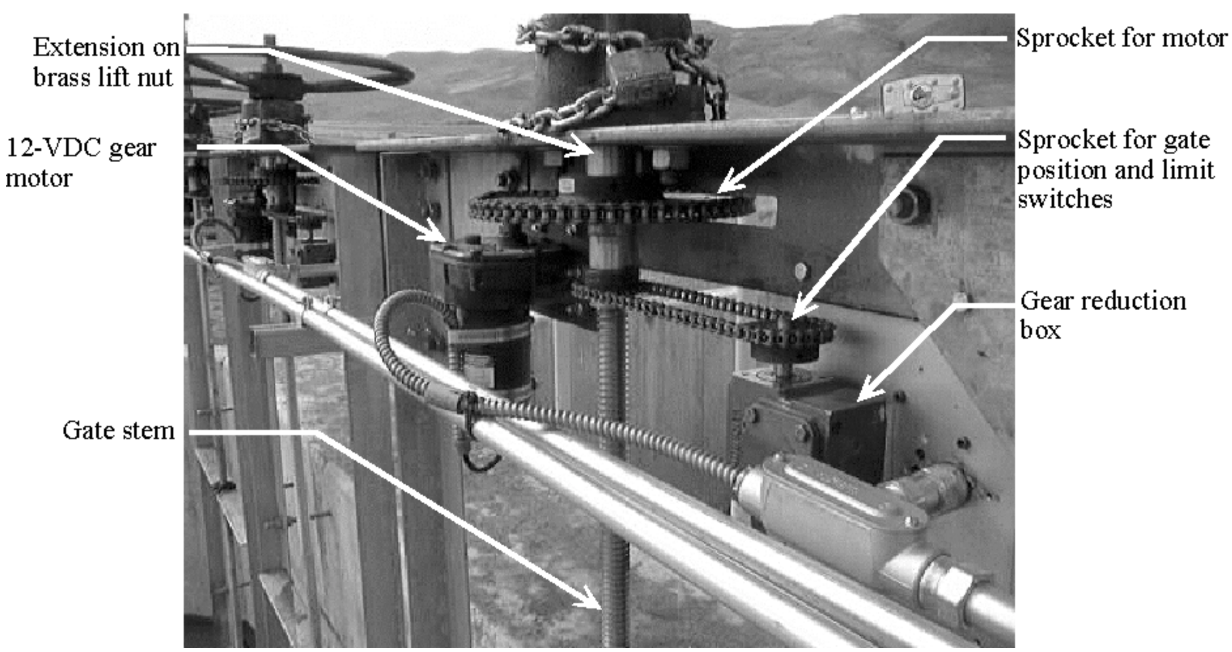

Fig. 4
The 12-VDC motor and second prototype are
attached to the brass lift nut on the gate stem.

Typical of the solar-powered field sites currently in operation is the diversion structure on the Sevier Valley/Piute Canal, Richfield, Utah, USA (see Fig. 5). The structure has four large slide gates (each is 2-meters square) which are moved up and down by fractional-horsepower 12-VDC motors. A 40-watt solar panel charges two deep-cycle (130 amp-hr) batteries which provide ample power for: four gate actuators, a radio telemetry system, sensors, and a data-logger/controller. The solar-powered automation system was retrofitted onto the existing structure using the first prototype described above.

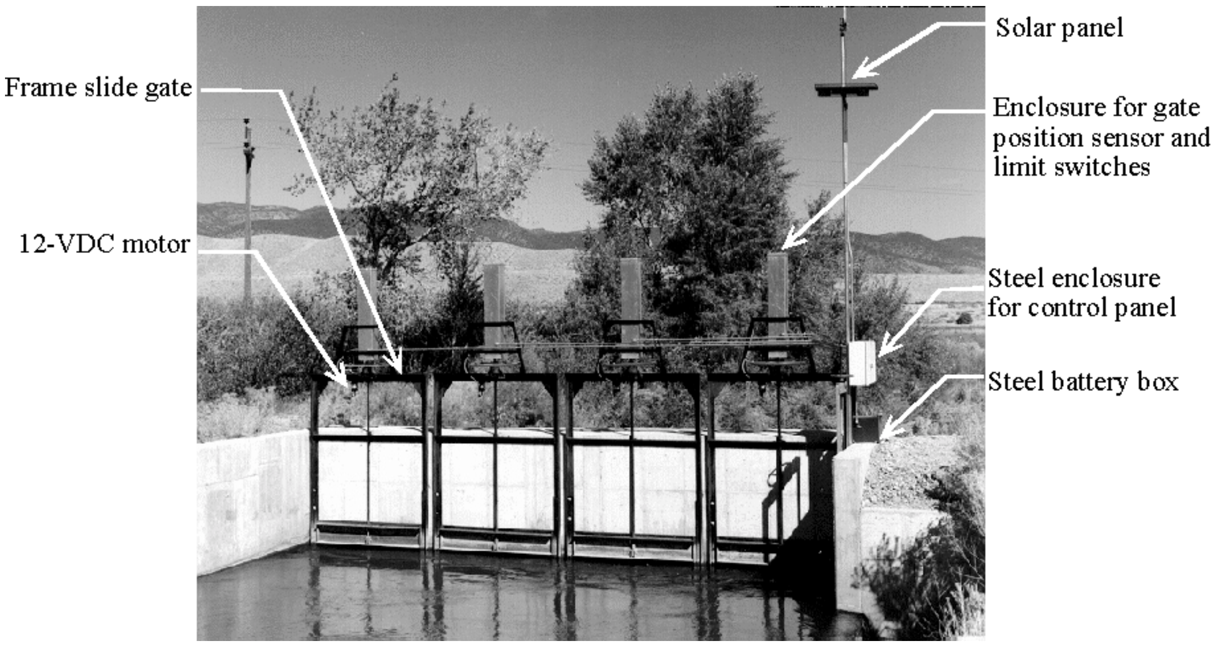

Fig. 5
The diversion structure for the Sevier Valley/Piute Canal illustrates the successful implementation of a solar-powered canal automation system.

The automation system operates in automatic remote control (the canal manager makes frequent changes in the flow target from his office or home). The gates adjust automatically to maintain a near-constant flow in the canal; they can move any time of the day or night. They are controlled by a modified-PI algorithm.

Over the last 7 years, Reclamation has installed over 25 solar-powered automated gate structures similar to the one in Fig. 5. They have proved to be very reliable.

Commercial Gate Actuators - While the example above uses a Ado-it-yourself@ type gate actuator, purchasing a 12- or 24-VDC commercial gate actuator is now possible. Today, AUMA and Rotork have DC models, as does Limitorque. Reclamation has installed several Limitorque 12-VDC actuators (Fig. 6). Most have been in operation for several years and have worked well. A typical commercial gate actuator costs between $3,500 and $6,000, excluding installation. The product comes with a manual control box, limit switches, a torque limit, and a gate position sensor.

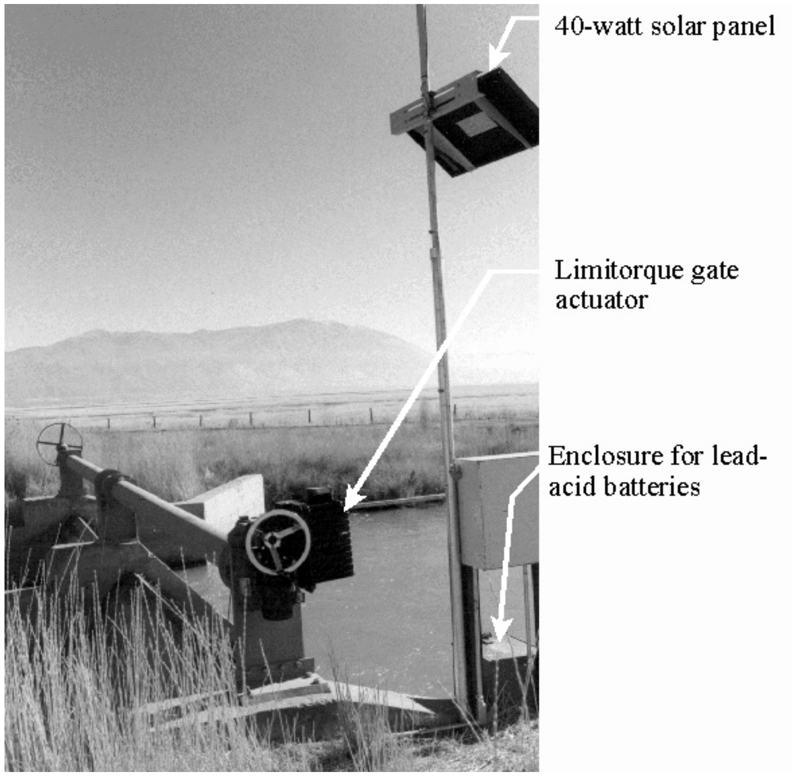

Fig. 6
This radial gate system on the Bear River Migratory Bird Refuge in northern Utah (USA) uses a solar-powered, commercially-available gate actuator.

Overshot Gates - There are a variety of solar-powered overshot retrofits which can be installed in a canal automation system. They include the: (1) draw-bridge gate; (2) pneumatic gate; and (3) scissor gate.

Drawbridge Gates. This overshot gate consists of a gate leaf, hinge, and hoist mechanism. One manufacturer is ARMTEC (www.big-o.com), a Canadian firm. This gate can be likened to a drawbridge hinged across the bottom of a vertical walled channel. When the gate is horizontal (fully open), water flows through the channel uninterrupted. As the cable hoist raises the downstream end of the gate, water flows over the lip while the channel sides restrict it. The hoist can be operated by a 12- or 24-VDC motor. Reclamation was involved in the successful installation of a ARMTEC gate in western Idaho (USA).

Pneumatic Crest Gate – Working with Obermeyer, Inc., in Ft. Collins, Colorado, USA (www.obermeyerhydro.com), overshot gates for use in check and similar structures have been tested. The Obermeyer gate is hinged across the bottom and moved up and down by an air

bladder. A small 12-VDC air compressor is used to inflate the bladder. In 1994, an Obermeyer gate water was retrofitted into a check structure of a canal in north central Utah [3]. The next year a larger gate was installed at the Bear River Migratory Bird Refuge in northern Utah.
Scissor Gate – One version of the scissor gate, invented by Peter Langemann, was patented by the St. Mary Irrigation District, Lethbridge, Alberta, Canada, and is manufactured and marketed by Aqua Systems 2000 Inc. (www.aquasystems2000.com). The gate is an arrangement of hinged leaves that function as an adjustable weir to provide either flow control or instream level control. Each gate is fully self-contained and incorporates a 12-VDC motor and gear reducer, limit switches, electrical control panel, and solar power supply. Reclamation was involved with successful installation of the Langemann gates on three separate irrigation systems in southern Idaho (see Fig 7).

Fig. 7
This solar-powered Langemann scissor gate regulates the flows out of a small water storage pond near Twin Falls, Idaho, USA

Sandia National Laboratories

Over the last 7 years, problems have been identified in some of the solar-powered sites, including shorter than anticipated battery life, reliability of the charge controllers, vandalism, and theft. In addition, as automation systems become more complex, sizing the solar-energy system is becoming increasingly important to provide reliable system operation.

To help eliminate future problems, Reclamation and Sandia National Laboratories have initiated a cooperative effort to determine what data and analysis are needed to anticipate impending system problems with these automated sites. Experience in anticipating problems at these photovoltaic powered sites is to be extended to other sites that use fixed power as well. The approach will be to monitor system parameters and use that real-time data for analysis. In addition to water levels used for gate control, system diagnostic measurements will be recorded that include current, voltage, and acceptable environmental conditions that describe normal system operation. Abnormal operating conditions can be recognized as deviations from this standard profile. This analysis can support a program of pro-active system maintenance to prevent or minimize downtime.

The solar energy system consists of several components. They are the photovoltaic (PV) modules, a battery for energy storage, and a charge controller that interfaces with the storage battery and the PV modules. The PV module converts the sunlight to electrical energy that can be stored in the battery for operation during the night or periods of reduced sunlight. A charge controller is used to protect the battery from being overcharged by the PV modules and it protects the battery from being too deeply discharged.

Photovoltaic modules are the most reliable component in this type of renewable energy system. Manufacturing and design have sufficiently improved so that 20-year lifetimes are attainable. Charge controllers are continuing to improve with expected increasing lifetimes as well. The storage medium of choice is still lead acid batteries in many applications. Batteries require continuing care to provide lifetimes that are cost-effective. Measurements of the load of the gate system are proposed so that the energy needs of the systems can be compared with the potential generation and storage capability of the PV modules and battery. These measurements are of the current and voltage required for gate operation. In addition temperature measurements in the battery compartment are needed since extreme temperatures can be a major factor in decreasing battery life.

The approach will be to monitor system parameters and use the real-time data for analysis. In addition to parameters required for gate control, system diagnostic measurements will be recorded that include current, voltage, and environmental conditions such as temperature. Data will be collected to establish normal operating profiles for system operation in terms of these current, voltage, and temperature measurements. System profiles may be created in terms of upper and lower limits, simple nomograms, or algorithms to monitor system operation. Abnormal operating conditions can be recognized as deviations from this standard profile. This analysis can support a program of pro-active system maintenance to prevent or minimize system failures.

In summary, techniques will be developed and implemented in the control program to recognize and alert the system operator of impending problems. Using the results of the Reclamation/Sandia collaboration, the results of the real-time analysis, including the health of the automation system, will be displayed on web sites to alert canal managers of potential problems.

This process has already begun. For example, the status of the Sevier Valley/Piute automation system (see Fig. 5) is displayed on a web site (www.sevierriver.org) which collects data every hour. One of the parameters which is monitored is battery voltage (see Fig. 8). This provides important information on the state of the solar-energy system, and is thus used to anticipate problems. In the future, additional troubleshooting parameters will be added to the system (i.e., current draw).

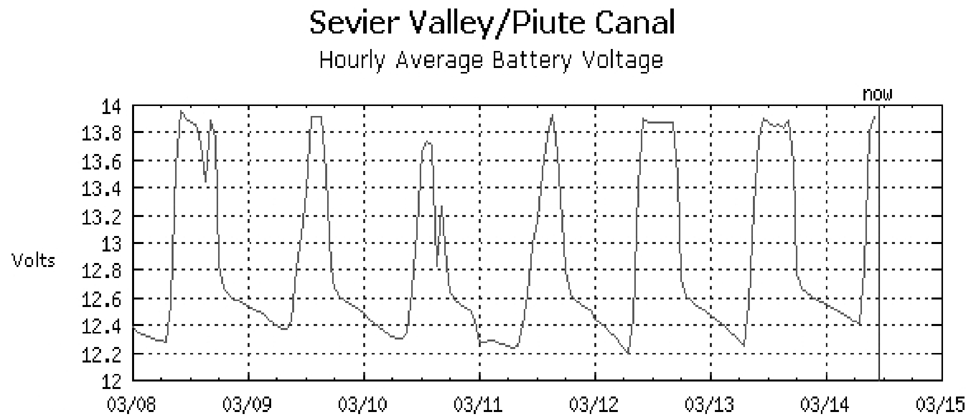

Fig. 8
Real-time displays of battery voltage can be a useful tool for troubleshooting solar-energy systems. This 7-day plot for a system in the Sevier River Basin (Utah, USA) is displayed on www.sevierriver.org

Conclusions

Low-cost water resource automation promises a revolution in improved water management. Today, automation systems are within the cost range of almost all water user groups, including irrigators, canal companies, flood control managers, municipal water suppliers, and water user groups. A critical component of modern automation projects are solar technologies.

Reclamation has been working with solar-powered automation systems for over 8 years. They have proved to be cost-effective and very reliable.

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